



## Inorganic Chemistry : Journey to Powerful Resource

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### 1. INTRODUCTION

Historically Inorganic chemistry is the oldest branch of chemistry and its origin can be traced to the knowledge acquired, presumably through accidental discoveries, by people in the very ancient civilizations as in Egypt, India and Mesopotamia (in India ca. 2500 B.C) (Roy P.C. 1956). In subsequent period the alchemists in China, in Egypt (ca 1200 – 1500 A.D) and later in Europe (ca 1200- 1500 A.D) despite their queer views and objective made discoveries that contributed to the advancement of this branch of Chemistry. Extraction of zinc from the minerals calamine was first achieved in India by the alchemist Nagarjuna (9<sup>th</sup> century A.D.). Birth of modern inorganic chemistry is rightly attributed to the French chemistry A.L.Lavoisier's systematic studies on the phenomenon of combustion that established (1772 A.D.) the role of oxygen in a combustion process leading to demolition of classical phlogiston theory of Becher and of Stahl (17<sup>th</sup> century).

### 2. DISCOVERY OF ELEMENTS

It is a useful parameter of progress in inorganic chemistry nearly 30 elements were discovered by 1800 A.D. and another 54 elements by 1900 A.D. while the rest were prepared in 20<sup>th</sup> century by nuclear reactions artificially. So far the highest element made and characterized is of atomic number 118 (un-un-octium)(Table - I). If graph is drawn of the discovery of elements vs time mirrors the pattern of developments in many other fields of science including chemistry. Some of the significant developments in inorganic chemistry and in other areas that impacted the progress in inorganic chemistry in the 19<sup>th</sup> century (Table - II).

**Table 1**

Period	Elements known
Prehistoric	C, S, Au
3000 B.C.	Ag, Cu, Pb, Sn, Hg
1200 B.C.	Fe
500 B.C.	Zn
1750-1800 A.D.	H, N, O, F, P, As, Te, Sb, Be, Ti, Cr, Mn, Co, Ni, Bi, Zr, Mo, W, Pt, U
1801-1863 A.D.	B, Si, Cl, Br, I, Se, Li, Na, K, Rb, Cs, Mg, Ca, Sr, Ba, Cd, Al, In, Tl, Y, La, Ce, V, Nb, Ta, Th, Pd, Ru, Rh, Os, Ir, Er, Di, Tb
1868-1899 A.D.	He, Ne, Ar, Kr, Xe, Se, Ga, Ge, Pr, Nd, Sm, Gd, Dy, Ho, Tm, Po, Ra, Ac, Yb
1903-1940 A.D.	Tc, Pm, Eu, Lu, Hf, Re, At, Fr, Pa
1944-1969 A.D.	Am, Cm, Bk, Cf, Es, Fr, Mv, No, Lr, Ku, Ha
By 1989 A.D.	Atomic number 106-109 (artificially)
By 1996 A.D.	Atomic number 110-112
By 2010 A.D.	Atomic number 113-118

The significant advances that took place in the 20<sup>th</sup> century, particularly since the 1950s, were due to advent of a number of sophisticated physico-chemical techniques that provided precise and detailed information on structures and bond features of molecular species. The developments in nuclear science provided further impetus to vigorous activity in inorganic chemistry. During the

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**Table 2 : Some Landmark Development in Chemistry in 19<sup>th</sup> Century**

Year	Significant
1803	Atomic Theory
1811	Avogadro's hypothesis
1827	Zeise salt
1829	Dulong and Petit's law
1832 -1833	Laws of electrolysis
1848	Zn (CH <sub>3</sub> ) Frankland
1852	Joule-Thomson effect
1858 -76	Cathode rays - Goldstein
1860 - 65	Determination of atomic weights
1867	Laws of mass action
1869	Periodic law
1873	Molecular weights -Victor mayor
1885	method
1886	separation of Di into Pr and Nd Ge,F,Al,N <sub>2</sub> H <sub>4</sub> (Curits)
1888	Theory of electrolytic dissociation
1889	Ni Mond process
1893	Activation energy (Arrhenius)
1894	Coordination Chemistry (Werner)
1895	He, Ne, Ar, Kr, Xe separation
1896	X rays
1897	Radioactivity
1898	e/m of cathode ray particles
1899	Ra and Po from pitchblende Ac (Debieme)
1900	Grignard reagent

last century there have been developments that considerably widened the domain of inorganic chemistry. The 20<sup>th</sup> century was indeed a golden age for inorganic

chemistry, one of intense activity and curiosity driven research and trend continuing (Mc Cleverty *et al.* 2004). Since the 1950s we also notice that the emergence of bioinorganic chemistry elucidating the role of metal ion in biological systems (Banerjea *et al.* 2000).

The Royal Society of Chemistry, UK Dalton division has held an international conference on inorganic chemistry jointly with the European Chemical Society at Manchester during April 11-14 in the year 2011. The invited lectures were delivered and sessions were held in the major areas of current activity in inorganic chemistry(a) Supramolecular Chemistry(b) Organo metallic Chemistry and catalysis (c)Reaction Mechanisms(d)Inorganic materials (e) Energy and Photo Chemistry (f)Bioinorganic Chemistry (g)Chemistry of main group elements(h)Solid state Chemistry.

### 3. NEED FOR TODAY AND TOMORROW

At the juncture of the 20<sup>th</sup> and 21<sup>st</sup> century it was realised that there is an urgent need for alternative and sustainable source of clean energy because of fast depletion of the natural fossil fuels<sup>4,5</sup> and the environmental pollution caused by their use. The total energy that reaches the earth from the sun in one hour is adequate to meet our present energy demand in the world. But the technology is yet to be developed for efficient and economical harnessing of solar energy. Nuclear energy is another option, but there are various problems associated with the production of nuclear energy, particularly the disposal of the highly radioactive spent fuel of nuclear power plants, apart from radiation hazard in case of an accident in a nuclear plant and a few such cases are already known such as the one at the Chernobyl plant in the erstwhile Soviet union during the eighties(1986) of the last century, another in the Three Mile Island in the USA and a recent one caused by a natural calamity at Fukushima (Japan) in the month of March 2011. Of various considerations hydrogen seems to have the potential to be the ideal fuel for the future, provided we can develop the technology for large scale production from our vast reserve of water using solar energy for splitting water forming H<sub>2</sub> and O<sub>2</sub> and overcome the problem of storage and transportation of hydrogen which is indeed challenging. Burning the

hydrogen produces water releasing considerable amount of usable energy and the water from which the hydrogen is generated is reproduced on burning the hydrogen making hydrogen a sustainable unending source of green energy. While gaseous or liquid hydrogen is currently an option for prototype motor vehicles, solid state storage of hydrogen is superior both in terms of storage capacity and safety (Dresselhaus *et al.* 2001). Hence storage of large quantity of hydrogen in a compact solid medium from which the hydrogen can be released easily and conveniently as and when needed is one of the challenges to be met for large scale use of hydrogen as a fuel and there is considerable ongoing activity in this area (Mandal *et al.* 2009) and the major developments during the period up to 2008 have been reviewed (Grochala *et al.* 2004). Several papers on s- block metals and their compounds either as components of MOF or amidoborane derivatives as hydrogen storage media appeared in the year 2009 (Schuth *et al.* 2004).

Both the uptake and release of hydrogen must be thermodynamically and kinetically favourable to be useful. The storage may be both chemical (as a compound) or physical (surface adsorption or interstitial adsorption in a porous frame work material) involving Vander Waals type interaction. Among the chemical storage materials studied so far are metals/metal alloys and their hydrides and complex hydrides (Sakintuna *et al.* 2007; Ziden *et al.* 2009; Orimo *et al.* 2007; Chen *et al.* 2008; Gregory *et al.* 2008) and various other hydrogen containing compounds.

#### 4. CHEMICALS TO RAGE MATERIALS

Among chemical storage materials we have several metal alloys : both  $\text{Mg}_2\text{Ni}$  (storage capacity 3.6% w/w Hydrogen) and  $\text{LaNi}_5$  (1.28% w/w) are two of the well studied examples. They have extraordinary cycle ability (Sandruck *et al.* 1999)  $\text{Fe}_{0.15}\text{Ti}_{0.84}\text{V}$  alloy has a storage capacity of 3.7% (Basak *et al.* 2007). Light metal hydrides like  $\text{MgH}_2$  (7.6% w/w) are important due to high storage capacity but have the disadvantage because of high temperature needed for desorption of hydrogen, as also unfavourable thermodynamics and kinetics. Despite such limitations  $\text{MgH}_2$  is one of the binary hydrides that is receiving much attention because of its light weight

and high storage capacity (Grant *et al.* 2008). Lot of much interest and research activity is going on in this field.

#### 5. CONCLUSION

Despite several advantages of such systems, the most serious draw back is the lack of facile reversibility which makes these compounds unsuitable for hydrogen storage applications. In the next ten years if we get the suitable storage material for hydrogen, in this environmental conscious era, then the role of chemistry and chemists is to develop processes and design products, which can either eliminate or minimize the generation of toxic by products and other pollution. We need to gradually clean up our sins of the past.

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